

# **APPLICATION FOR UNITED STATES PATENT**

**in the name of**

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**for**

**Photovoltaic Array**

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## **PHOTOVOLTAIC ARRAY**

### **CLAIM OF PRIORITY**

This application is a continuation of U.S. Application No. PCT/US02/36743, filed November 15, 2002, which claims priority to U.S. Application No. 60/380,862, filed May 17, 2002, and is a continuation-in-part of U.S. Application No. 09/993,875, filed November 16, 2001, now U.S. Patent No. 6,617,507, each of which is incorporated by reference in its entirety.

### **TECHNICAL FIELD**

This invention relates to a photovoltaic array including a plurality of photovoltaic modules that are mounted on a support surface such as the ground, a ground pad, or a roof, etc. for receiving sunlight to generate electricity.

### **BACKGROUND**

An important aspect of manufacturing photovoltaic arrays is the manner in which the photovoltaic modules utilized are manufactured such as disclosed by United States Patents 5,248,349 Foote et al., 5,372,646 Foote et al., 5,470,397 Foote et al., 5,536,333 Foote et al., 5,945,163 Powell et al., and 6,037,241 Powell et al. In addition to the processing and apparatus utilized to manufacture the photovoltaic modules per se, the mounting and assembly of the modules into an array, which is referred to in the photovoltaic art as "balance of systems", is important. Prior art patents involving the balance of systems in the photovoltaic art include: 4,189,881 Hawley, 4,760,680 Myers, 4,966,631 Matlin et al., 5,092,939 Nath et al., 5,143,556 Matlin, 5,316,592 Dinwoodie, 5,505,788 Dinwoodie, 5,746,839 Dinwoodie, 6,061,978 Dinwoodie et al., 6,065,255 Stern et al. and German Patent Document DE 3611542 Melchoir. The aforementioned 5,746,839 Dinwoodie patent discloses a photovoltaic assembly having a photovoltaic module with a spacer secured to a lower surface of the module and sized and configured

to define an open region beneath the lower surface and access openings formed therein for fluidly coupling the open region to the upper surface with the access openings extending along at least two sides of the photovoltaic module. The aforementioned German Patent Document DE 3611542 Melchoir discloses a photovoltaic array that is  
5 mounted on a roof and has photovoltaic modules mounted adjacent each other spaced upwardly from the roof to allow air flow below the modules.

### SUMMARY

An improved photovoltaic array includes a plurality of photovoltaic modules for being mounted on a support surface such as the ground, a ground pad, a roof, etc.

10 The photovoltaic array can include a plurality of elongated rails for being mounted on the support surface projecting upwardly therefrom and extending in a spaced and parallel relationship to each other. Each rail has an extruded resin construction including a lower base and an upper cap that are secured to each other and cooperate to define a pair of grooves that open in opposite lateral directions from each other. The  
15 photovoltaic array can also include rectangular photovoltaic modules having edges that are received by the grooves of the rails so as to be mounted above the support surface in a spaced relationship from the support surface.

The lower base and upper cap of each rail are preferably extruded as separate pieces and secured to each other to define the oppositely opening pair of grooves.

20 The photovoltaic modules are preferably arranged in pairs with the modules of each pair abutting each other, and each pair of photovoltaic modules is spaced along the elongated lengths of the rails from each adjacent pair of modules to provide openings therebetween. The photovoltaic modules disclosed have elongated rectangular shapes that have lengths about twice as long as widths thereof, and each pair of photovoltaic  
25 modules has elongated edges along lengths thereof abutted with each other. Each pair of modules thus has a generally square shape extending between an associated pair of the elongated rails.

The photovoltaic array can include cross members that extend between the lower bases of the rails to space the rails from each other. These cross members are located within openings between the photovoltaic modules. Electrical wiring of the photovoltaic array is supported by the cross members which have upwardly opening shapes that receive the electrical wiring. More specifically, the cross members have a lower floor and a pair of sides that extend upwardly from the lower floor in a converging shape toward each other and have upper edges that are spaced from each other.

As mentioned above, the elongated rails of the photovoltaic array preferably have the two piece lower base and upper cap construction. In one embodiment, each lower base includes a lower flange for mounting on the support surface, a stem that projects upwardly from the lower flange, and an upper extremity of a T shape that defines an upwardly opening slot extending along the elongated length of the elongated rail. Each upper cap has a T shape including a stem that projects downwardly and is received by the slot in the T-shaped upper extremity of the lower base. Each upper cap also has an upper cross bar that extends in opposite directions from the stem thereof to cooperate with the T-shaped upper extremity of the lower base in defining the pair of grooves that open in opposite directions from each other to receive edges of the photovoltaic modules that are mounted by the rails on the support surface.

The upper extremity of the lower base of each rail has a pair of upwardly projecting stops respectively located on opposite sides of the slot to position the modules horizontally with respect to the rails.

The elongated rails have the lower flange of the lower base provided with a greater lateral width along the elongated length thereof than the T-shaped upper extremity of the lower base and the upper cross bar of the upper cap. Also, the stem of the lower base has scallops for reducing the resin utilized.

In an alternate embodiment of the two piece rail construction, the lower base has a lower end for mounting on the support surface, a stem that projects upwardly from the lower end, an upper extremity of a T shape that defines an upwardly opening slot

extending along the length of the elongated rail, and the upper extremity of the lower base includes downwardly extending flanges for securing flashing.

Fasteners secure the upper cap of the two piece rail construction to the lower base of the rail, and the upper cap includes an elongated extruded formation that facilitates centering alignment of drilled holes for receiving the fasteners.

The photovoltaic array has the lower bases and the upper caps of the two piece elongated rails extruded from a first resin and has the grooves of the rails provided with pads of a second material that is softer than the first resin to accommodate for thickness variations. More specifically, the lower base is extruded entirely from the first resin and the upper cap is coextruded from the first resin and a second resin which constitutes the second material that provides the pads which are located on the upper cross bar within the grooves.

In another embodiment of the two piece rail construction, the upwardly opening slot of the lower base and the downwardly projecting stem of the upper cap have connection formations for providing securement of the upper cap to the lower base.

The cross members of the photovoltaic array are supported by and extend between the T-shaped upper extremities of the lower bases of the rails within openings between the photovoltaic modules to space the rails from each other. These cross members have elongated shapes extruded from resin within an upwardly opening shape and, as previously mentioned, electrical wiring is received by the upwardly opening cross members.

In one use disclosed, the photovoltaic array has its support surface embodied by a roof having a membrane on which the rails are mounted. It is also possible to utilize connections that secure the lower bases of the rails to the membrane of the roof. These connections can be embodied by bonds between the lower bases of the rails and the membrane on the roof, and the bonds between the lower bases of the rails and the membrane on the roof can be autogenous. The connections can also include connector sleeves that slidably receive the lower bases of the rails, and this construction of the

connections also includes bonds that secure the connector sleeves to the membrane on the roof. More specifically, the connector sleeves are made of the same material as the membrane on the roof, and the bonds between the connector sleeves and the membrane on the roof are autogenous. In another embodiment, the connections include elongated  
5 connector strips, the lower bases of the rails have openings through which the connector strips extend, and the connector strips have ends secured to the membrane on the roof. More specifically, the connector strips are made of the same material as the membrane on the roof and the ends of the connector strips have autogenous bonds that provide the securement to the membrane on the roof.

10 In another aspect, a method of deploying a photovoltaic module on a support surface includes providing a photovoltaic module including a panel having an elongated edge that extends along an elongated axis of the panel and a transverse edge having a length less than the length of the elongated edges and extending substantially perpendicular to the elongated axis, and an attachment member extending along the  
15 elongated edge, and coupling the attachment member to a support segment extending along a direction substantially perpendicular to the elongated axis such that the attachment member is isolated from the support surface.

In another aspect, a method of deploying a photovoltaic module on a support surface includes attaching attachment members to a pair of parallel edges of a panel to  
20 form a photovoltaic module, the attachment members extending along an elongated axis, coupling the attachment members to a support segment extending along a direction substantially perpendicular to the elongated axis, and coupling the support segment to a support surface such that the panel is isolated from the support surface.

In another aspect, a method of deploying a photovoltaic array includes providing  
25 a plurality of photovoltaic modules, each photovoltaic module having a panel having an elongated edge that extends along an elongated axis of the panel and a transverse edge having a length shorter than the length of the elongated edges and extending substantially perpendicular to the elongated axis, and an attachment member extending along the

elongated edge, positioning attachment members on support segments extending along a direction substantially perpendicular to the elongated axis in a spaced and parallel relationship to each other, and coupling the support segments to a support surface such that the attachment members are isolated from the support surface. Providing a plurality of photovoltaic modules can include attaching the attachment member to the elongated edge of the photovoltaic module. In certain circumstances, providing a plurality of photovoltaic modules can include forming the photovoltaic modules such that each photovoltaic module is able to be isolated from other photovoltaic modules.

In another aspect, a photovoltaic array includes a plurality of photovoltaic modules, each module having a panel having an elongated edge that extends along an elongated axis of the panel and a transverse edge having a length shorter than the length of the elongated edges and extending substantially perpendicular to the elongated axis, and an attachment member extending along the elongated edge. The array also includes a plurality of support segments positioned on a support surface and extending along a direction substantially perpendicular to the elongated axis, each support segment being in a spaced and substantially parallel relationship relative to each other. The attachment member couples each photovoltaic module to at least two support segments such that the panels are isolated from the support segments and the attachment members are isolated from the support surface.

In another aspect, a photovoltaic array includes a plurality of support segments positioned on a support surface and extending along a support axis, each support segment being in a spaced and substantially parallel relationship to each other. The array also includes a plurality of photovoltaic modules, each photovoltaic module having a panel having an elongated edge and a transverse edge having a length shorter than the length of the elongated edge and extending perpendicular to the elongated edge, and an attachment member attached to elongated edges of each photovoltaic module and coupled to a support segment such that the elongated edges of the photovoltaic module are substantially perpendicular to the support axis. The panels are isolated from the support

segments and the attachment members are isolated from the support surface when the attachment member is coupled to the support segment.

5 In another aspect, a photovoltaic module includes a panel including an elongated edge that extends along an elongated axis of the panel, and a transverse edge having a length that is shorter than the length of the elongated edge and extending substantially perpendicular to the elongated axis, and an attachment member extending along the elongated edge of the panel.

10 In another aspect, a photovoltaic array deployment system includes a plurality of support segments, a plurality of photovoltaic modules, each module having a panel having an elongated edge and a transverse edge having a length shorter than the length of the elongated edges and extending substantially perpendicular to the elongated edge, and an attachment member extending along the elongated edge and configured to couple to a support segment.

15 The method can include attaching the attachment member to the elongated edge of the module. Attaching the attachment member to the elongated edge includes positioning the attachment member on the elongated edge such that the attachment member projects away from the elongated edge and substantially parallel to a surface of the panel.

20 The support segment can include a rail. The support segment can only contacts attachment members and the support surface.

25 The photovoltaic module can include a second elongated edge that extends along the elongated axis, and a second attachment member extending along the second elongated edge. The method can further include coupling the second attachment member to a second support segment extending along a direction perpendicular to the elongated axis.

Coupling the attachment member to the support segment can include positioning the attachment member relative to the support segment such that the support segment extends along a portion of the transverse edge that is shorter than the total length of the



transverse edge. In certain embodiments, coupling the attachment member to the support segment can include positioning the attachment member relative to the support segment such that the panel is isolated from the support segment.

The objects, features and advantages of the present invention are readily apparent from the following detailed description of the preferred embodiments for carrying out the invention when taken in connection with the accompanying drawings.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

FIGURE 1 is a perspective view illustrating one embodiment of a photovoltaic array constructed in accordance with the invention to include photovoltaic modules mounted on a support surface that is illustrated as being embodied by a roof.

FIGURE 2 is a top plan view of another embodiment of a photovoltaic array constructed in accordance with the invention but having a greater number of photovoltaic modules than the embodiment of Figure 1.

FIGURE 3 is a top plan view on an enlarged scale from that shown in Figures 1 and 2 to illustrate the construction of the photovoltaic array.

FIGURE 4 is a sectional view taken along the direction of line 4-4 in Figure 3 to illustrate the manner in which elongated rails of the photovoltaic array support photovoltaic modules by receiving their edges.

FIGURE 5 is a partial sectional view taken along the direction of line 5-5 in Figure 3 to illustrate the manner in which cross members extend between and are connected to lower bases of the elongated rails to provide spacing and support between the rails.

FIGURE 6 is a sectional view taken along the direction of line 6-6 in Figure 3 to illustrate the construction of the cross members.

FIGURE 7 is a partial view that illustrates the manner in which a lower flange of a lower base of the elongated rail may be bonded to a roof membrane.

FIGURE 8 is a view similar to Figure 7 of another embodiment which includes a sleeve for securing the lower base flange to the roof membrane.

FIGURE 9 is a perspective view illustrating another manner in which the lower base of the rail is secured to the roof membrane by connector strips.

5        FIGURE 10 is a view similar to Figure 4 of another embodiment wherein an upper cap of the elongated rail is secured to the lower base by connection formations.

FIGURE 11 is a view illustrating another embodiment of the elongated rail which has particular utility for use with steep roofs.

FIGURE 12 is a plan view of a photovoltaic array.

10       FIGURE 13 is an enlarged plan view of a portion of the photovoltaic array of Figure 12.

FIGURE 14 is a plan view of a photovoltaic module used in the photovoltaic array of Figure 12.

15       FIGURE 15 is a sectional view of the photovoltaic module taken along section 15-15 of Figure 14.

FIGURE 16 is an enlarged perspective view of a portion of an attachment member in the photovoltaic module of Figure 15.

FIGURE 17 is a plan view of support members coupled to the photovoltaic module of Figure 15.

20       FIGURE 18 is a sectional view of the support member and photovoltaic module taken along section 18-18 of Figure 17.

FIGURE 19 is an enlarged sectional view of Figure 18.

FIGURE 20 is an enlarged perspective view of a portion of the support member and the photovoltaic module of Figure 17.

25       FIGURE 21 is an enlarged perspective view of a portion of an attachment member that may be used in the photovoltaic module of Figure 15.

Like reference symbols in the various drawings indicate like elements.

### DETAILED DESCRIPTION

With references to Figures 1 and 2, two different embodiments of a photovoltaic array constructed in accordance with the invention are respectively indicated by 20 and 20' and are the same as each other except for the number of rectangular photovoltaic modules 22 included in each array. More specifically, the photovoltaic array 20 illustrated in Figure 1 has a six by four module size so as to include twenty four photovoltaic modules 22, while the photovoltaic array 20' of Figure 2 has a six by ten size so as to include sixty photovoltaic modules 22. In the Figure 1 embodiment, the photovoltaic array 20 is mounted on a support surface 24 which is embodied by a roof 26. In the embodiment of Figure 2, the photovoltaic array 20' is mounted on a support surface 24' which may be a roof, the ground, a ground pad, or any other support surface.

With continuing reference to Figures 1 and 2, each embodiment of the photovoltaic arrays 20, 20' includes a plurality of elongated rails 28 that are mounted on the associated support surface 24, 24' projecting upwardly therefrom and extending in a spaced and parallel relationship to each other. Each of the rails 28 as illustrated in Figure 4 has an extruded resin construction including a lower base 30 and an upper cap 32 that cooperate to define a pair of grooves 34 opening in opposite directions from each other. The rectangular photovoltaic modules 22 have edges 36 that are received by the grooves 34 of the rails 28 so as to be mounted above the support surface 24 in a spaced relationship therefrom, which will nominally be about four inches, although the spacing can vary but normally will be in the range of about two to six inches.

In the preferred embodiment illustrated, the elongated rails 28 have a two piece construction with the lower base 30 and the upper cap 32 being extruded separately from each other and secured to each other to define the oppositely opening grooves 34. This two piece construction facilitates the assembly of the photovoltaic arrays by allowing the base 30 to be initially positioned on the support surface so as to receive the edges 36 of the photovoltaic modules 22 prior to securement of the caps 32 to their associated bases.

While it is also possible to extrude the base 30 and cap 32 as a unitary construction, the assembly of the photovoltaic array is then somewhat more difficult to achieve since the photovoltaic modules edges must be inserted into the grooves sideways rather than being able to be placed downwardly in the manner that can be done with the two piece construction.

The photovoltaic modules 22 as shown in Figures 1 and 2 are preferably arranged in pairs 38 with the modules of each pair abutting each other, and with each pair 38 of photovoltaic modules being spaced along the elongated lengths of the rail from each adjacent pair to provide openings 40 therebetween. More specifically, the photovoltaic modules 22 illustrated in Figures 1 and 2 have elongated rectangular shapes with lengths about twice as long as their widths, nominally about four feet by two feet. Each pair 38 of the photovoltaic modules 22 has elongated edges 36 along their lengths thereof abutted with each other as illustrated so that each pair of modules has a generally square shape that will nominally be about four feet by four feet as illustrated. Thus, the short edges 36 of the module widths are received and supported by the elongated rails 28. While this is the preferred construction in providing increased size of the openings 40 for any given size of module area in order to facilitate ventilation, it should be appreciated that the photovoltaic modules can also have their shorter widths abutted and their longer lengths received by the elongated rails 28 to provide support of the modules on the support surface.

As illustrated in Figures 1-3 and 5, each embodiment of the photovoltaic array includes cross members 42 that extend between the lower bases 30 of the rails 28 to space the rails from each other. The cross members 42 as best illustrated in Figure 3 are located within the openings 40 between the photovoltaic modules 22 and are secured to the lower bases 30 by fasteners 43 such as self tapping screws as is hereinafter more fully described. Electrical wiring 44 best illustrated in Figure 6 is supported by the cross members 42 which have upwardly opening shapes that receive the electrical wiring. More specifically, the cross members 42 as shown in Figure 6 have a lower floor 46 and a pair of sides 48 that extend upwardly from the lower floor with an inclination in a

converging shape toward each other and have upper edges 50 that are spaced from each other to permit the wiring to pass into and out of the cross members as illustrated so that all of the photovoltaic modules of the array can be connected into an appropriate circuit for collection of the electrical power generated. The inclined construction of the cross member sides 48 causes wind to provide a hold down force to the photovoltaic array.

With reference to Figure 4, the elongated rails 28 each has the lower base 30 of its two piece construction provided with a lower flange 52 for mounting on the support surface 24, a stem 54 that projects upwardly from the lower flange 52, and an upper extremity 56 of a T shape that defines an upwardly opening slot 58 extending along the elongated length of the elongated rail.

With continuing reference to Figure 4, the elongated rails 28 each also has the upper cap 32 of its two piece construction provided with a T shape including a stem 60 that projects downwardly and is received by the slot 58 in the T-shaped upper extremity 56 of the lower base 30. The upper cap 32 also has an upper cross bar 62 that extends in opposite directions from the stem 54 thereof to cooperate with the T-shaped upper extremity of the lower base in defining the pair of grooves 34 that open in opposite directions from each other to receive the edges 36 of the photovoltaic modules 22 that are mounted by the rails 28 on the support surface 24.

With further reference to Figure 4, the lower base 30 of each rail 28 has a pair of upwardly projecting stops 64 located on opposite sides of the slot 58 to position the photovoltaic modules horizontally upon assembly of the photovoltaic array. More specifically, the lower base 30 is initially secured to the support surface such that the photovoltaic modules 22 can be placed downwardly thereon with the stops 64 providing horizontal positioning in a lateral direction with respect to the elongated direction of the rails. The caps 32 can then be secured to the lower bases 30 as is hereinafter more fully described to complete the assembly of the photovoltaic array in an efficient manner.

It will also be noted in Figure 4 that the stem 54 of the lower base 30 has scallops 65 extruded along its length to reduce the amount of resin utilized. It will be further

noted in Figure 4 that the elongated rails 28 have the lower flange 52 of the lower base 30 provided with a greater lateral width along the length thereof than the T-shaped upper extremity 56 of the lower base and than the upper cross bar 62 of the upper cap 32, which provides stability in the mounting.

5           With reference to Figure 11, a modified embodiment of the elongated rail 28' has a construction with particular utility for use on steep roofs. More specifically, the lower base 30' of this rail embodiment has a generally steeple shape cross section including a lower end 52 that is mounted on the support surface 24 and extends upwardly therefrom with a converging shape to the upper extremity 56'. At its upper extremity 56', the lower  
10 base 30' has the same upwardly opening slot 58 as the previously described embodiment as well as having the stops 64 previously described. The lower base upper extremity 56' also has a pair of downwardly extending flanges 66 for securing flashing 67 that extends downwardly to the support surface 24 and then laterally to the adjacent rails and upwardly to thus provide an elongated weather tight seal between the rails. Screws  
15 within associated counterbored holes can be utilized to secure the lower base 30' to the support surface. The extruded cap 32 utilized with this embodiment is the same as the previously described embodiment.

As illustrated in Figures 3 and 4, fasteners 68 secure the upper cap 32 to the lower base 30 and will normally be embodied by suitable self tapping screws. The upper cap  
20 32 includes an elongated extruded formation 70 along its centerline between the opposite ends of the cross bar 62. This extruded formation 70 facilitates centering alignment of drilled holes 72 (Figure 4) for receiving the fasteners 68 which are spaced at suitable intervals along the length of the rail.

With continuing reference to Figure 4, both the lower base 30 and the upper cap  
25 32 of the elongated rail are extruded from a first resin such as a rigid polyvinyl chloride, and the grooves 34 of the rail include pads 74 of a second material that is softer than the first resin to accommodate for thickness variations in the photovoltaic module edges 36 received by the grooves. More specifically, the lower base 30 is extruded entirely from

the first resin and the upper cap 32 is coextruded from the first resin and a second resin such as a flexible polyvinyl chloride which constitutes the second material and provides the pads 74 which are located on the upper cross bar 62 within the grooves 34.

5 In another embodiment illustrated in Figure 10, the rails 28 have the upwardly opening slot 58 of the lower base 30 and the downwardly projecting stem 60 of the upper cap 32 provided with connection formations 76 and 78 for providing securement of the upper cap to the lower base by a snap action.

As illustrated in Figure 5, the cross members 42 are supported by and extend between the upper T-shaped extremities 56 of the lower bases 30 of the rails 28 and are  
10 located as shown in Figure 3 within the openings 40 between the adjacent pairs of the photovoltaic modules 22. These cross members 42 have elongated shapes extruded from resin, such as about a rigid polyvinyl chloride, with an upwardly opening shape as previously described, and the electrical wiring 44 is received by the upwardly opening cross members as illustrated and as was previously described in connection with Figure 6.

15 As shown in Figure 5, the cross members 42 have their ends supported on and secured to the T-shaped upper extremity 56 of the lower base 30 by the fasteners 43. These cross members 42 facilitate the proper spacing of the rails 28 from each other during the assembly as well as supporting the rails in their mounted locations after the assembly.

20 It is also possible to use spacers within the grooves 36 of the elongated rails 28 to ensure that the pairs 38 of photovoltaic modules are properly spaced from each other. These spacers can remain as permanent components of the photovoltaic array or can be removed prior to the final securement of the upper cap 32 to the lower base 30.

The photovoltaic array in many applications may have its elongated rails 28  
25 mounted by the associated support surface 24 without any securement or ballast required to provide a hold down function. Thus, the rail 28 illustrated in Figure 4 may merely sit upon the support surface 24 illustrated to provide the mounting of the photovoltaic array. Connections can also be provided to secure the lower bases to the support surface.

As illustrated in Figure 7, the support surface 24 as previously mentioned may be a roof and the roof may have a membrane 80 that can be of different materials such as polyvinyl chloride, ethylene propylene diene monomer, chlorinated polyethylene, rubber or a built-up roof (BUR) of asphalt or coal tar pitch and felt.

5 As illustrated in Figures 7-9, the photovoltaic arrays can also have connections between the lower bases 30 of the rails and the membrane 80 of the roof. These connections can be bonds 82 between the flanges 52 of the lower bases of the rails and the membrane, with the bonds being autogenous as can be provided by heat bonding that is most easily performed when the membrane 80 is of the same material as the base. As  
10 illustrated in Figure 8, it is also possible for the connections to be provided by connector sleeves that slidably receive the lower bases 30 of the rails such as at the lower flange 52 thereof as illustrated, and the connections include bonds 86 that secure the connector sleeves to the membrane 80 of the roof. Such bonds 86 between the connector sleeves 84 and the membrane 80 can be autogenous and provided by heat bonding that is most easily  
15 performed with the same material providing both the roof membrane and the connector sleeve.

As illustrated in Figure 9, the connections between the rails and the roof membrane can also include connector strips 88, with the lower bases 30 of the rails 28 having openings 90 through which the connector strips extend, and the connector strips  
20 have ends 92 secured to the membrane 80 on the roof. More specifically, the connector strips 88 are made of the same material as the membrane 80 on the roof and the ends 92 of the connector strips have autogenous bonds 94 that provide the securement thereof to the roof membrane such as by heat welding.

Referring to Figures 12-14, a photovoltaic array 1200 includes 60 photovoltaic  
25 modules 1205 arranged in a  $6 \times 10$  array. Each module 1205 includes a panel 1400 having an elongated edge 1405 that extends along an elongated axis 1410 of the panel 1400 and a transverse edge 1415 that extends substantially perpendicular to the elongated axis 1410. The transverse edge 1415 has a length that is shorter than the length of the



elongated edge 1405. The array 1200 includes support segments 1215 positioned on a support surface (such as surface 24 in Figure 1). The support segments 1215, like the elongated rails 28, can be made of an extruded resin construction.

Referring also to Figures 15 and 16, the module 1205 has an attachment member 1500 extending along the elongated edge 1405 of the panel 1400. The attachment member 1500 is formed with a surface 1505 that projects away from the elongated edge 1405 and is substantially parallel with the surface of the panel 1400. The substantially parallel positioning can be within 20°, within 15°, within 5°, or within 1° of being absolutely parallel. This arrangement can facilitate coupling between the attachment member 1500 and the support segment 1215, as detailed below. To reduce the weight of the array 1200, the attachment member 1500 is formed to have a hollow area 1510 that extends along the elongated edge 1405. The attachment member 1500 may be made of any suitable material, such as, for example, aluminum. Other materials include other metals, plastics, and glasses. The material of the attachment member 1500 may be selected based on the mechanical or electrical properties of the panel 1400 and/or the support segment 1215. Thus, for example, the material of the attachment member 1500 may be selected to match the coefficient of thermal expansion of the panel 1400.

Referring also to Figures 17-20, the attachment member 1500 is attached to the elongated edge 1405 of the module 1205 to provide for coupling of the module 1205 to the support segment 1215, as discussed below. The attachment member 1500 may be attached to the elongated edge 1405 using adhesive or any suitable technique. The attachment member 1500 extends the length of the elongated edge of a single panel 1400. Thus, each module 1205 has two attachment members 1500.

Deployment of the photovoltaic array 1200 includes coupling the support segments 1215 to the support surface such that the support segments 1215 extend along a direction that is substantially perpendicular to the elongated axis 1410. Furthermore, each of the support segments 1215 is in a spaced and substantially parallel relationship with the other support segments 1215. Then, each of the attachment members 1500 is

positioned on an associated support segment 1215. In this way, the modules 1205 are arranged in the photovoltaic array 1200 such that the transverse edges 1415 abut each other and the elongated edges 1405 are separated from each other by openings 1300 or 1305.

5           An attachment member 1500 may be positioned on an associated support segment 1215 by abutting the transverse edge 1415 of the module 1205 to an abutment surface 1900 of the support segment 1215. Then, to provide additional support, the attachment member 1500 may be attached the support segment 1215 using a screw 1905 that is sized to fit into a threaded hole 1910 of the support segment 1215.

10           The arrangement of the array 1200 has several advantages. For example, because the photovoltaic modules are formed with attachment members 1500, the deployment of the array 1200 is simplified. The photovoltaic modules may be manufactured ahead of time. Then, upon shipment of a deployment system that includes the photovoltaic modules and the support segments, the installer can simply position the support segments  
15 on the support surface and then positioned the photovoltaic modules on the support segments. The installer can install one module at a time without needing to lift or position the other modules. Moreover, the installer need not slide the module into a long track or rail but simply positions or places the modules on the support segments.

          Moreover, to facilitate the free flow of air through array 1200 when assembled,  
20 the attachment member 1500 contacts a relatively small area of the support segment 1215 and is isolated from (that is, not touching) the support surface. Furthermore, the modules are arranged with openings between elongated edges. Air flow is also facilitated because the panel is isolated from the support segments, which are in turn isolated from each other, and the module is isolated from the support surface.

25           The attachment members 1500 also provide structural integrity to the photovoltaic modules while permitting the free flow of air because the exposed elongated edges of the modules are supported by the attachment members 1500. The transverse edges do not

benefit from additional structural support because these edges abut each other once the array is deployed.

Other implementations are within the scope of the following claims.

For example, as shown in Figure 21, the attachment member may be formed as a  
5 solid bar 2100.

The support segments may be formed like a segment of an elongated rail, such as the lower base 30 of the elongated rail 28. The support segments may be coupled to the support surface in the same manner as detailed with respect to coupling of the elongated rail 28 to the support surface.

10 The openings 1300 and 1305 may have different widths or one of the openings may have a width that is larger than the width of the other opening.

The photovoltaic array may be formed of any suitable number of photovoltaic modules and support members depending on the size of the support surface and the require energy output of the array.

15 Because of the modular deployment system, the photovoltaic array may be formed as an inclined array, with one end of a module slightly overlapping the end of an adjacent module. Such a system is shown, for example, in U.S. Patent No. 5,746,839.

The array can include an airfoil on at least one end of the array. For example, the airfoil can be a bar having a face angled relative to the support structure. The airfoil can  
20 extend along the surface of the support structure and can project above the plane of the panel. The airfoil alters airflow in the region of the array to create a force holding the array on the support structure.

While the preferred embodiments of the invention have been described in detail, those familiar with the art to which this invention relates will recognize various  
25 alternative designs and embodiments as defined by the following claims.